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RESEARCH ARTICLE

Prevalence and Correlates of Hypertension and Elevated Blood Pressure among School-Age Children in Khartoum, Sudan: A Cross-Sectional Study

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Abstract: ***Background***: The escalating burden of hypertension (HTN) is a global health concern, with origins often in childhood. Data on the prevalence and correlates of pediatric HTN in Sub-Saharan Africa, particularly Sudan, remain scarce. This study aimed to determine the prevalence of HTN and elevated blood pressure (BP) and their association with age, sex, obesity, and family history among school-aged children in Khartoum North, Sudan. ***Methods:*** Multi-stage stratified random sampling was used to select 428 schoolchildren aged 6–14 years from primary schools, Khartoum north locality, Khartoum, Sudan. Interviewer-administered questionnaires, anthropometric, and BP by auscultation in a standardized fashion were recorded. Hypertension was systolic and/or diastolic BP ≥95th percentile, and elevated BP was ≥90th to <95th percentile (or ≥120/80 mm Hg for adolescents), for age, sex, and height. ***Results:*** The mean age of participants was 9.88 years, with 55.4% being female. The prevalence of HTN was 4.0% (95% CI: 2.1–5.9%), and elevated BP was 6.1% (95% CI: 3.8–8.4%). Hypertension was significantly more prevalent in adolescents (8.3%) than in pre-adolescents (3.4%) ($p<0.001$) and in obese children (16.7%) compared to normal-weight children (1.8%) ($p<0.001$). No significant associations were found with gender ($p=0.154$) or family history of HTN ($p=0.256$). ***Conclusion:*** The current research identifies a high prevalence of HTN and elevated BP among Sudanese children with strong association with obesity and adolescence. These findings create a need for including repeated BP screenings and multilevel public health interventions for the management of childhood obesity in school health curricula in Sudan as well as in other settings.

Keywords: Hypertension, Elevated Blood Pressure, Pediatrics, Obesity, Prevalence, Sudan, Sub-Saharan Africa.

INTRODUCTION

Systemic hypertension (HTN) in childhood used to be an uncommon clinical phenomenon, nearly exclusively related to secondary etiologies, yet it is now a relevant public health problem due to the worldwide increase in childhood obesity [1-3]. It is also understood to function as a prominent, modifiable risk factor for childhood cardiovascular disease of early onset and adult organ damage, with the development of atherosclerosis typically starting in adolescence [4]. As such, the early recognition of elevated blood pressure (BP) in offspring is an important preventive measure [5].

New American Academy of Pediatrics clinical guidelines suggest frequent BP assessment in children as young as 3 years of age [6]. Pediatric HTN prevalence is diverse globally, based on definitions, methods of measuring BP, and population-related factors such as obesity rates, socioeconomic status, and ethnicity [7,8]. Survey data from national high-income countries and new Asian and Latin American reports indicate prevalence of 2% or higher to more than 6% for HTN and much higher for elevated BP [9,10].

Nonetheless, there is a large knowledge gap for most locations in Sub-Saharan Africa. Crisp, community-based data from these regions are scarce, and the particular genetic, dietary, and environmental settings of these populations could present different epidemiological signatures [11]. Sudan, with its dynamic demographic and nutrition transition, is especially underserved. This research sought to establish the prevalence of HTN and raised BP and to examine their correlation with important demographic and anthropometric parameters among schoolchildren in Khartoum North Locality, Sudan. The results are indispensable for national public health planning and for the global childhood HTN literature.

MATERIAL AND METHODS

2.1. Study Design and Setting

This descriptive, cross-sectional study was conducted from July through December 2022 in Bahri Administrative Unit, in Khartoum North Locality, Khartoum, Sudan.

2.2. Study Population
Children from primary school aged between 6 and 14 years were the study participants. Exclusion was for Children with congenital heart disease, chronic renal disease, or with some important chronic systemic diseases.

2.3. Sample Size and Sampling Method
The sample was estimated to be 378 by using the formula for a finite population, while maintaining the confidence at 95%, the margin of error at 5%, and the prevalence (p) at 0.5. To compensate for potential non-response, the estimated final sample was adjusted upwards to 428. A stratified random sampling method was utilized. Initially, four educational institutions (comprised of two public and two private schools, stratified by gender) were chosen at random. Following this, children were selected from each school and grade utilizing a proportional-to-size and simple random sampling methodology.

2.4. Data collection tool
The Questionnaire and Anthropometry: An interviewer-administered, pre-tested questionnaire was used for collecting sociodemographic information and family history of HTN. Weight was recorded to the nearest 0.1 kg with an electronic weighing scale, and height was recorded to the nearest 0.1 cm with a stadiometer. BMI was computed, and BMI percentiles were derived from the CDC growth charts. Overweight and obesity were used as BMI ≥85th to <95th percentile and ≥95th percentile, respectively.

Measurement of Blood Pressure: BP was measured in the patient's right arm with a calibrated mercury sphygmomanometer and appropriate cuff, according to the Fourth Report and the AAP Clinical Practice Guideline in 2017 [6,12]. Two BP readings were taken after a 5-minute rest, at least 10 minutes apart, with a trained researcher. The average of the two reading values was used for analysis. BP status was classified as normal, elevated, or hypertensive by age, sex, and height percentiles [6].

2.5. Statistical Analysis
The data were analyzed with SPSS software version 23.0. Descriptive statistics were available as mean ± SD for continuous data, as well as frequencies (%), for categorical data. The Chi-square test was utilized for estimation of relationships of hypertension status with categorical factors (age group, gender, family history, BMI category). Statistical significance was determined by a p-value of < 0.05.

2.6. Ethical Considerations
The study was conducted in accordance with the ethical standards in the 1975 Declaration of Helsinki. Ethical approval (FPEC-45-2022) was obtained from the Ethical Committee of the Faculty of Pharmacy, University of Khartoum. Additionally, appropriate administrative approval was also secured from participating schools. Written informed consent was obtained from all the guardians of the patients. The participants' information confidentiality and anonymity were strictly maintained during the study period.

RESULTS

3.1. Participant Characteristics
A total of 428 children participated in the study. The mean age was 9.88 ± 2.15 years, with 55.4% being female. The majority (88.8%) were pre-adolescents (6-12 years). The mean weight, height, and BMI were 33.3 ± 12.4 kg, 137.6 ± 13.2 cm, and 17.2 ± 3.86 kg/m², respectively. The mean systolic and diastolic BP were 96.71 ± 12.23 mm Hg and 58.59 ± 10.77 mm Hg, respectively. Most children had weight (86.2%), height (90.2%), and BMI (64.7%) within the normal range (5th to 85th percentiles).

3.2. Prevalence of Hypertension and Elevated Blood Pressure
The overall prevalence of HTN was 4.0% (n=17), and the prevalence of elevated BP was 6.1% (n=26). Thus, one in ten children (10.1%) had some form of elevated BP reading (Figure 1).

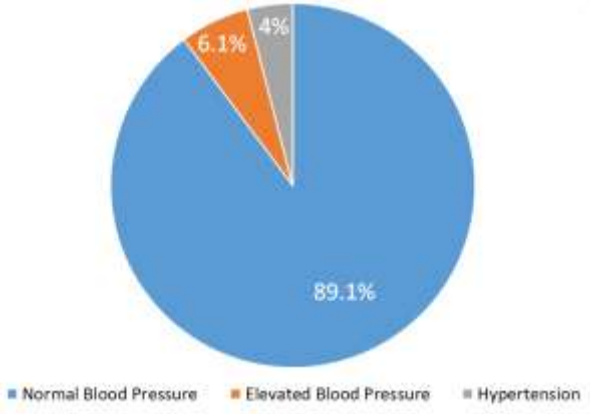

Figure 1. Prevalence of HTN and elevated BP distribution among study participants (n= 428)

3.3. Associations with Hypertension

A strong and statistically significant association was observed between HTN status and age group, with adolescents having a higher prevalence ($p<0.001$). There was no significant difference in HTN prevalence between males and females ($p=0.154$). A positive, but non-significant, association was noted with a family history of HTN (5.6% vs. 2.6%, $p=0.256$) (Table 1).

Table 1. Prevalence of Hypertension and Elevated Blood Pressure by Age, Gender, and Family History of Hypertension (n= 428)

Characteristic	Category	Normal BP (n, %)	Elevated BP (n, %)	Hypertension (n, %)	P-value
Age Group	6-12 years (n=380)	351 (92.4%)	16 (4.2%)	13 (3.4%)	**<0.001**
	13-14 years (n=48)	34 (70.8%)	10 (20.8%)	4 (8.3%)	
Gender	Male (n=191)	177 (92.7%)	10 (5.2%)	4 (2.1%)	0.154
	Female (n=237)	208 (87.7%)	16 (6.8%)	13 (5.5%)	
Family history of hypertension	Yes (n=197)	173 (87.8%)	13 (6.6%)	11 (5.6%)	0.256
	No (n=231)	212 (91.8%)	13 (5.6%)	6 (2.6%)	

Furthermore, as shown in Table 2, a highly significant association was found with BMI category ($p<0.001$). The prevalence of HTN was 16.7% (10/60) in obese children, compared to 3.6% (1/28) in overweight and 1.8% (5/277) in normal-weight children.

Table 2. Association between Hypertension and Body Mass Index (BMI) Category

BMI Category	Normal BP (n, %)	Elevated BP (n, %)	Hypertension (n, %)	Total	P-value
Underweight (n= 61)	62 (98.4%)	0 (0.0%)	1 (1.6%)	63	**<0.001**
Normal Weight (n=277)	258 (93.1%)	14 (5.1%)	5 (1.8%)	277	
Overweight (n=28)	24 (85.7%)	3 (10.7%)	1 (3.6%)	28	
Obese (n=60)	43 (71.7%)	7 (11.7%)	10 (16.7%)	60	
Total	387	24	17	428	

DISCUSSION

HTN represents a significant long-term health issue characterized by multiple contributing factors, such as genetic, behavioral, and environmental determinants [13]. A growing body of evidence suggests that the onset of this condition often commences in childhood, highlighting the necessity to assess its prevalence and related risk factors across various populations [14,15]. This school survey of Sudanese schoolchildren reports a prevalence of HTN of 4.0% and of higher BP of 6.1%. These prevalences match recent reports from diverse global environments, including India (3.4%) and Argentina (3.7%) [10,16].

However, this prevalence was much higher than previous reports, such that from Amritsar city, India (0,46%) (17), most likely an outcome of the variation in diagnostic criteria as well as the modification in way of life over the years, like the rising prevalence of physical inactivity and obesity. There is also the suggestion from the latest studies of declining prevalence rates, like those by Souza et al. (2.1%) and Sabapathy et al. (2.7%), where repeated BP measurements over three consecutive visits were conducted—a process that provides enhanced diagnostic accuracy [18,19]. In the case study by Souza et al., the prevalence of hypertension dropped from 8.1% during the first visit to 2.1% during successive measurements [18].

The most important findings of our study demonstrate significant associations between HTN and both the adolescent age group and obesity. The roughly five times higher risk of HTN in adolescents with obesity compared with their age-matched counterparts of normal weight (16.7% vs. 1.8%) identifies obesity as the most important modifiable risk factor in this population. This is completely in accordance with global data that identifies the rise in BP accompanying excess adiposity as a key contributor to the childhood HTN epidemic [20-22]. Additionally, the higher prevalence in adolescents is consistent with physiological trends and may further be contributed by lifestyle factors at this life stage.

Although some studies revealed gender differences [23-25], in the current study our data revealed no statistical significance between males and females, which is in line with previous report from China [9]. These discrepancies are probably due to ethnic, genetic, and way of living differences between populations. Furthermore, non-significance of family history, while unexpected, can similarly be attributed to being based on self-reports or the youth of the cohort, in whom etiologic predispositions by family may not yet be realized.

Our findings must be interpreted considering certain limitations. The cross-sectional design precludes causal inference. The inability to conduct follow-up visits due to political during the study period means we could not

confirm persistent HTN, potentially leading to an overestimation of true prevalence due to white-coat effect. Furthermore, reliance on BMI alone may underestimate the contribution of central adiposity. Also, the sample was also small and only generalizable to one geographic location.

Despite these limitations, the public health implication is huge. The finding that 8.3% of an adolescent population in school settings has higher blood pressure values is a particular call for action. This highlights the urgent need for the widespread integration of blood pressure screening as a part of regular school health service in Sudan. It also demands the development and implementation of national primary preventive strategies for promoting physical exercise and nutritional well-being to combat obesity in children.

CONCLUSION

This report offers significant background information for the prevalence of hypertension in schoolchildren in Sudan. The observed 4% prevalence of hypertension, highly correlated with adolescence as well as with obesity, identifies an increasing but substantial cardiovascular risk burden. These findings strongly indicate a policy shift for early case finding and primordial prevention, with school environments as significant sites for protection of the cardiovascular health of generations to come.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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